King Fahd University of Petroleum & Minerals

College of Environmental Design

Construction Engineering & Management Department

CEM 530

Construction Equipment & Methods

Spring 2004/2005

Construction Equipment & Methods

- Construction Engineering fundamentals
- Equipment economics
- Selection and efficient application of equipment
- Analyzing construction outputs

Categories of Equipment

Mounting:

- **Wheel-mounted.**
- **Chain-mounted (Crawler).**

Power delivery to wheels:

- **Two-wheel drives.**
- **Four-wheel drives**

Construction Engineering Fundamentals

Resistances

1. **Rolling Resistance (RR).**

   RR is a combination of retarding forces opposing movement of a wheel vehicle over level terrain.

2. **Grade Resistance (GR).**

   GR is the retarding forces of gravity which must be overcome to move vehicles uphill. GR becomes assistance if the vehicle moves downhill.

Rolling Resistance (RR)

- Expressed in pounds (lb.) and caused primarily by:

1. Penetration of a tire or wheel into the roadway.

2. Flexing of the tire.

- Caused to a lesser degree by:

1. Internal friction of bearings and gears.

- Acts only on wheel-type units

RR = Weight on wheels (tons) × Rolling resistance value (lb./ton)

RR values per ton of gross weight

Road conditions	Resistance values lb./ton
Hard, smooth surface with no tire penetration (well maintained).	40
Firm, smooth surface, flexing slightly under load (well maintained).	65
Flexible dirt roadway (irregular surface with approximately one inch of tire penetration)	100
Flexible dirt roadway irregular surface with up to 4 inches of tire penetration.	150
Soft, muddy, irregular roadway or sand with over six inches of tire penetration.	220-400

Example

Calculate the RR of a rubber tired vehicle of 15-ton gross weight, moves on a firm and smooth gravel road that slightly flexes under load.

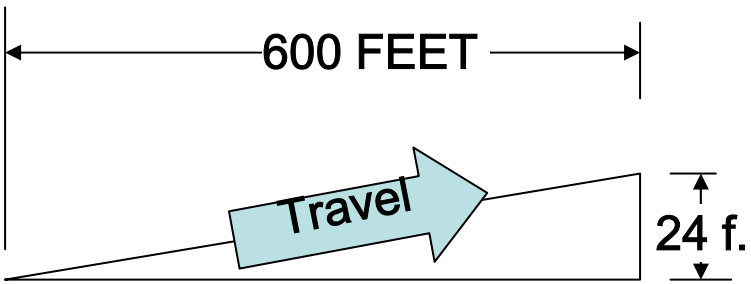
Solution

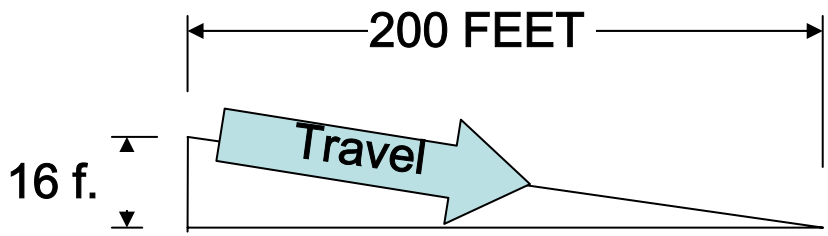
From the table of the RR value, the RR for this road is 65 lb./ton

RR = 15 tons × 65 lb./ton = 975 lb.

Grade Resistance (GR)

- Acts on crawler or wheel-type units.
- Grades are measured in percent of slope.





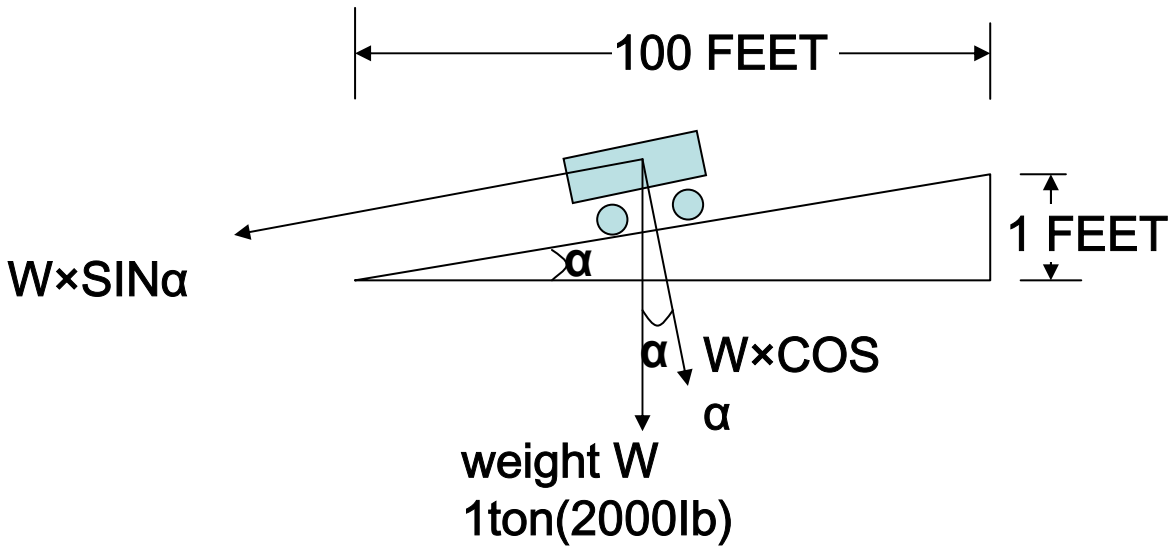
24/600 = 0.04 or 4% adverse (-)

16/200 = 0.08 or 8% favorable (+)

Grade resistance (GR)

- **Measured in pounds per ton per percent of grade.**

GR = 20 lb./ton × percent of grade × weight in tons



$$GR = W \times \sin \alpha$$

For small angles $\sin \alpha = \tan \alpha = \alpha$

$$GR = 2000 \times 1/100 = 20 \text{ lb.}$$

Example

An empty hauling unit weighing 30 tons were travelling up a 6% grade, calculate the encountered grade resistance.

Solution

$$GR = 20 \times 6 \times 30 = 3{,}600 \text{ lb.}$$

Rimpull required

- Rimpull is a term used to describe the pushing force exerted by the tire against the ground.
- According to Newton's law of that a body starts to move when forces equal resistances.
- The rimpull require to move a vehicle is the total of rolling resistance and grade resistance
- Rimpull required = RR + GR

Example

A rubber-tired vehicle of 20 tons weight, travels on a road of 100 lb./ton RR value, calculate the required rimpull if it:

a) moves up a grade of 10%

b) Moves down a grade of 2%

Solution

a) Rimpull required = RR + GR

= 20×100 + 20×10×20 = 6,000 lb.

b) Rimpull required = RR + GR

= 20×100 - 20×2×20 = 1,200 lb.

Summary

- We are now able to determine the amount of rimpull required to move a rubber-tired vehicle over various types of terrain (Rimpull required).
- The next step is to determine how much rimpull the vehicle can develop to propel itself over these types of terrain (Available-usable rimpull).
- Match Rimpull required against Available-usable rimpull

Available-usable rimpull

A tractor provides AVAILABLE rimpull and offers USABLE rimpull. Both types must be considered at this point, and the lesser of the two must be used in all computations.

Available rimpull

- It is the amount of mechanical force the engine put through the transmission and final drive, and deliver at the point where the drive tire contacts the ground.
- While this power is actually available for use, WHEEL SLIPPAGE IS NOT CONSIDERED and depending on underfoot conditions, some of this force may be wasted in wheel spin.

Available rimpull

Specifications of a rubber-tired tractor shows the AVAILABLE rimpull the tractor can develop in each gear.

Alternatively, it can roughly be estimated using the following formula.

$$Available \quad rimpull = \frac{HP \times 375 \times f}{S}$$

HP: engine horsepower.

f: efficiency of gear train and ranges from 70% to 85%.

S: speed shown in various gears in Miles Per Hour

Example

Calculate the available rimpull if the engine is of 101 horsepower, the tractor travels in third gear at 3.7 MPH, and the efficiency of the gear is 82.8%.

$$Available \quad rimpull = \frac{101 \times 375 \times 0.828}{3.7}$$

= 8,475 lb.

USABLE rimpull

USABLE rimpull takes wheel slippage into consideration.

It is the actual amount of pull (expressed in lb.) the tractor offers at the point where the tractor tire contacts the ground.

It deals only with the actual weight on the drive wheels and the friction between the tire and the ground.

Engine horsepower is not considered when determining USABLE rimpull.

USABLE rimpull

USABLE rimpull can be estimated if we can approximate the amount of wheel slippage the tractor encounters on various type of roads.

The traction between the tires and ground must be considered.

The traction factor is the percent of the weight on the drive wheels which can be utilized as pulling or pushing effort.

Traction factor varies mainly with the type of material on which the unit is operating and partially with the tread design of tires.

USABLE rimpull

Ground material	Traction factor
Concrete	0.90
Clay Loam, dry	0.55
Clay Loam, wet	0.45
Rutted Clay Loam	0.40
Loose Sand	0.30
Quarry pit	0.65
Gravel Road (loose)	0.36
Packed Snow	0.20
Ice	0.12
Firm Earth	0.55
Loose Earth	0.45
Coal, Stockpiled	0.45

USABLE rimpull

USABLE rimpull = Traction factor × Weight on drive wheels

Example

Determine the USABLE rimpull of a hauling unit weighing 30,000 lb. with 14,350 lb. on the drive wheels, operating on firm earth.

Solution

From table the traction factor for firm earth is 0.55.

USABLE rimpull = 0.55 × 14,350 = 7,892 lb.

AVAILABLE-USABLE rimpull

It is the lesser of the AVAILABLE rimpull and the USABLE rimpull.

Refer back to the last two examples;

-Availble rimpull = 8,475 lb.

-Usable rimpull = 7,892 lb.

The weight on drive wheels is not sufficient to prevent the wheels from slipping.

The tractor can actually offers only 7,892 lb. of usable rimpull, the difference (583 lb.) is wasted in wheel slippage.

SUMMARY

STEP 1--- ROLLING RESISTANCE

you must add:

STEP 2--- GRADE RESISTANCE (Subtract grade assistance)

to obtain:

STEP 3--- RIMPULL REQUIRED

which must be matched against:

STEP 4--- AVAILABLE-USABLE RIMPULL

to determine:

STEP 5--- TRAVEL SPEED (MPH)

Travel speed

Specification sheets show the available rimpull in each gear along with travel speeds in MPH.

Example

A scraper is carrying a maximum load of material

-the gross weight is 61,950 lb. with 50.2% on drive wheels.

-The machine will travel over a firm earth road of 0.55 traction factor.

- The road has a rolling resistance value of 65 lb./ton.

- It will negotiate an adverse grade of 4%.

Travel speed

Solution

Rolling resistance = 61,950/2000 × 65 = 2,015 lb.

Grade resistance = 20 × 4 × 61,950/2000 = 2,480 lb.

Rimpull required = 2,015 + 2,480 = 4,495 lb.

Usable rimpull = 61,950 × 0.502 × 0.55 = 17,104 lb.

From specs sheets, the available rimpull in the 4 th. Gear is 4,900, so the machine can operate on the 4 th. Gear at a speed of 10 MPH.

Travel speed

-Travel speed can be calculated using the performance chart as follows:

-Calculate the rimpull required expressed as per grade.

$$\mathrm{Re}quired \quad rimpull = \frac{Grade \quad resis\tan ce + Rolling \quad resis\tan ce}{20 \times total \quad weight \quad in \quad tons}$$

-Locate the intersection of vertical vehicle-weight with the diagonal total resistance line.

-Extend a horizontal line from the point of intersection till it intersects the gear curve, and use it to calculate speed.

Example

A scraper is carrying a maximum load of material

the gross weight is 25 ton with 50% on drive wheels.

The machine will travel over a firm earth road of 0.50 traction factor.

The road has a rolling resistance value of 65 lb./ton.

It will negotiate an adverse grade of 4%.

Calculate the travel speed.

Example

Solution

Rolling resistance = 25 × 65 = 1,625 lb.

Grade resistance = 20 × 4 × 25 = 2,000 lb.

Rimpull required = 1,625 + 2,000 = 3,625 lb.

Rimpull require as % grade = 3,625 / (20×25) = 7.25%

The scraper can travel on 5^{th} gear at 11 mile per hr.

Check

Usable rimpull = 25 ×2000 × 0.50 × 0.50 = 12,500 lb.

Since usable rimpull is higher than the Rimpull required there will not be slippage.